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Evaluation of Ponderosa Pine Reforestation Techniques in Central Arizona

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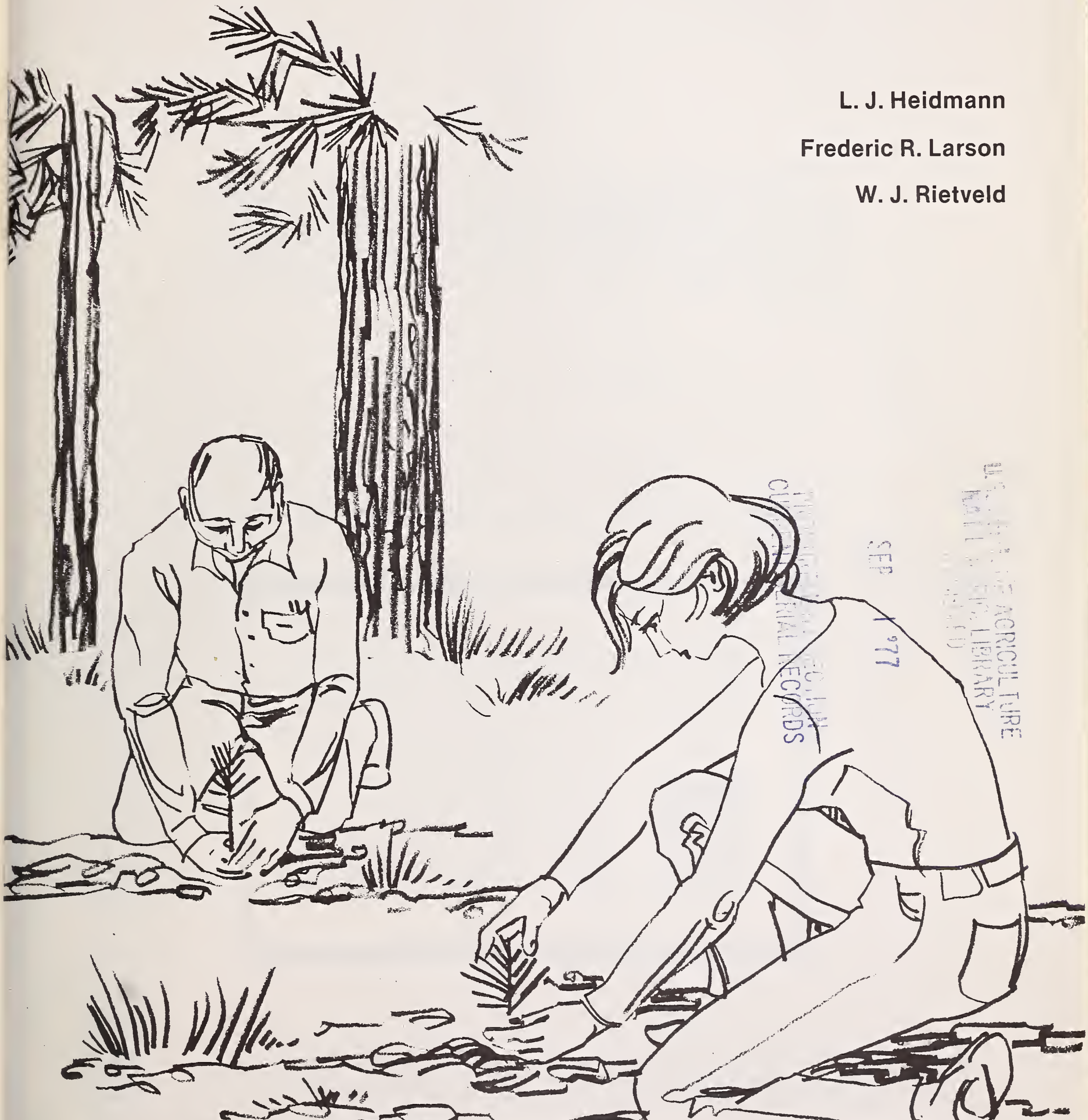

Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

Results from many studies of ponderosa pine regeneration—seeding, planting, and natural—over the past 15 yr on several areas on and near the Beaver Creek watershed in central Arizona indicate that seeding offers little hope of success. The failure of direct seeding is attributed to seasonal drought intensified by clay soils and competing vegetation. Tree planting has been consistently more successful.

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Contents

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Management Implications

Ponderosa pine should not be seeded on clay soils. Results from the experiments described here and other studies indicate the chances for success are slim (Rate 1957, Larson 1961, Pearson 1950). Water in clay soils is held so tightly that, even though the total water content of the soil may be fairly high, much of it is unavailable to seeds or seedlings (Pearson 1950). Successful seeding is much more likely on coarser soils derived from limestone or some sandstones. According to Pearson (1950), "summer showers penetrate the lighter soils (soils low in clay content) most readily, and since pine trees are deep rooted, this difference in penetration may prove to be a vital factor if rains are deficient. Stones tend to aid penetration, and since their absorptive capacity is low, the water which falls on them is concentrated in the soil proper."

Survival of natural regeneration is best on stony, gravelly, or sandy sites, and the same is true for planted trees. Regeneration has been difficult in swales or flats on relatively fine alluvial soils, while sites that are so stony that planting holes can only be dug with great difficulty have given good survival (Pearson 1950).

The increasingly high cost of ponderosa pine seed and site preparation makes direct seeding almost as costly as planting. Seeding in spots, which is recommended, is more costly than broadcast seeding, and may be more expensive than planting.

Results from natural regeneration surveys are not encouraging, either. Most of the areas are greatly understocked, and seedlings are growing in heavy competition. Stocking is increasing over time on many areas, but far below a rate acceptable for efficient timber production.

Planting offers a much greater chance of success than seeding, and is recommended for clay soils. Planting programs must be carefully planned, however. Several basic principles must be followed to insure success (Schubert et al. 1969, Heidmann 1963). A half-hearted attempt will only lead to failure. Competing vegetation should be eliminated before planting begins. Healthy, vigorous stock should be planted carefully on areas from which livestock have been excluded. Trees should not be planted when soil moisture is deficient. In some instances this may mean that trees already lifted may have to be destroyed. This is less costly, however, than spending additional thousands of dollars in a hopeless cause.

Containerized plantings in the Southwest generally have been unsuccessful. Much of the failure can be attributed to small planting stock (4½-in plugs) and a lack of site preparation. In the Pacific Northwest, ponderosa pine seedlings are raised in 6-in plastic tubes which are ribbed on the inside (Gutzwiller and Winjum 1974). The ribs help to reduce root spiraling, thereby eliminating a major problem of container-grown trees (Elam and Koelling 1974, Hiatt and Tinus 1974).

Larger containerized trees recently have been planted in the Southwest. Care needs to be taken, however, in growing larger trees to insure that the tops are not too tall and spindly. A proper relationship between tops and roots should be maintained.

Background

Planting is the most reliable method of regenerating ponderosa pine (*Pinus ponderosa* var. *scopulorum*) in Arizona. Successful plantations result when healthy trees are planted carefully on well-prepared sites from which cattle are excluded (Heidmann 1963, Schubert et al. 1970, Schubert 1974). Regeneration by natural or artificial seeding, on the other hand, generally has been a failure. Seeding has been unsuccessful primarily because of seed-eating rodents, inadequate soil moisture coupled with competing vegetation, and frost heaving. In addition, many of the soils in northern Arizona have a fairly high clay content. Clay soils hold water more tenaciously than coarser soils, which makes initial seedling establishment difficult. According to Haasis (1921) the limiting soil types for ponderosa pine in Arizona are the "clayey" and the "cindery."

During the past 15 yr, a number of reforestation studies and regeneration inventories have been conducted on the Beaver Creek watershed in north-central Arizona. This paper is a summary of published and unpublished results from these studies.

Beaver Creek Watershed Study Area

The Beaver Creek watershed was established in the mid-1950's to test the effect of various cultural practices on water production. The watershed is a part of the Verde River drainage system, and consists of approximately 275,000 acres (430 mi^2).

Four vegetative types are found within its borders (Worley 1965). Semidesert vegetation characterizes the lowest elevations (3,100 ft), while ponderosa pine is found at the higher elevations—up to 8,500 ft. Between are the alligator juniper (*Juniperus deppeana*) and Utah juniper (*J. osteosperma*) types.

In the ponderosa pine zone, the average annual precipitation is approximately 25 in. (Worley 1965, table 1). The pine stands are dotted with Gambel oak (*Quercus gambelii*), alligator juniper and New Mexican locust (*Robinia neomexicana*). The ground cover is primarily bottlebrush squirreltail (*Sitanion hystrix*), muttongrass (*Poa fendleriana*), and blue grama (*Bouteloua gracilis*). Soils above 7,000 ft in elevation, where these studies were conducted, are mainly derived from basalts and cinders. Typical soil profiles down to about 3 in are silty loams or clays, underlain by clays or silty clay subsoils (Worley 1965).

The main watershed is divided into 18 smaller watersheds, 12 of which contain ponderosa pine.

Regeneration Studies

Jones Mountain

The first regeneration study was installed at Jones Mountain, approximately 40 mi south of Flagstaff, in 1960 (Heidmann 1963). Four plant-

Table 1.—Precipitation (inches totals also in cm) during the course of several regeneration studies on various subwatersheds at Beaver Creek, 1960 through 1974.

	1960	1967	1968	1971		1972		1973		1974	
Month	JM[1]	W-12	W-12	W-9	W-14	W-9	W-14	W-9	W-14	W-9	W-14
Jan.	2.38	0.79	1.58	0.58	0.74	0.00	0.00	1.73	2.36	4.81	5.07
Feb.	4.75	.00	2.06	1.82	2.33	.13	.13	3.58	4.87	.22	.23
Mar.	1.22	1.20	1.89	.56	.72	.00	.00	10.58	14.40	1.89	1.99
Apr.	.95	1.31	2.05	1.21	1.55	.45	.47	1.55	2.10	.89	.91
May	1.81	.21	.45	1.24	1.03	.25	.21	.65	.91	.00	.00
Jun.	.34	1.92	.41	.00	.00	3.07	2.65	1.00	.33	.00	.00
Jul.	.67	8.05	2.65	.57	.61	2.99	3.99	3.64	1.54	3.11	2.37
Aug.	3.15	1.70	2.71	5.61	6.09	1.85	2.30	2.35	.89	1.70	1.48
Sept.	1.29	3.01	.03	2.85	2.47	1.04	.69	.00	.00	1.63	1.32
Oct.	2.72	.38	1.87	5.47	5.66	11.20	12.74	.00	.00	3.46	2.53
Nov.	1.03	1.54	1.87	.77	.80	3.27	3.72	2.59	3.15	.48	1.36
Dec.	1.65	4.37	1.89	4.16	4.31	4.78	5.43	.29	.35	1.99	1.45
Totals											
(in)	21.96	24.48	19.46	24.84	26.31	29.03	32.33	27.96	30.90	20.18	18.71
(cm)	(55.78)	(62.18)	(49.43)	(63.09)	(66.83)	(73.74)	(82.12)	(71.02)	(78.49)	(51.26)	(47.52)

[1]*Jones Mountain*

ing methods were tested on an area burned by wildfire in 1959.

Little vegetation was present when seedlings were planted, but by July 1960, grasses seeded in 1959 were growing vigorously. In 1961, grasses were well established (fig. 1).

Another detrimental factor was browsing by elk. Although few trees were killed by browsing alone, this factor, coupled with heavy competition from grass, undoubtedly stressed the seedlings severely and made establishment difficult.

Despite the adverse effects of elk browsing and competition the first year, subsequent growth of trees was excellent, and the area is now well-stocked:

Planting methods	Stocking	
	1961	1975[2]
	Percent	
Standard depth, no mulch	64	72
Standard depth, three-rock mulch	68	81
Deep planting, no mulch	58	80
Deep planting, three-rock mulch	56	70
Overall average	62	76

[2]*Based on point stocking survey (Lexen 1939). Stocking has increased because as trees grow larger fewer are required for full stocking.*

Figure 1.—The Jones Mountain planting site at time of tree planting in 1960 (left),1 yr later (right) showing stand of orchard grass which has matured following seeding.

The study site was protected from livestock, while an adjacent area planted at the same time was left open (fig. 2). The protected area is 76% stocked, while the grazed area is essentially nonstocked. Few trees died after the first two seasons, and growth has been rapid. A few trees which were protected from browsing grew in height from 12 to 14 in the first year, which is exceptional for ponderosa pine in Arizona.

Watershed 12

A ponderosa pine planting study was established on a cleared watershed (Watershed 12, fig. 3) in 1967 (Rietveld and Heidmann 1974) to test

Figure 2.—A general view of the fenced Jones Mountain study site (left) 16 yr after planting, and an adjacent area (right) not protected from livestock browsing. Differences in overall ponderosa pine stocking are dramatic.

Figure 3.—An aerial view of the 455-acre Watershed 12 after clearing and windrowing of slash.

the influence of the following mulching treatments on survival and growth:

- Petroleum mulch, a water emulsion of petroleum resins sprayed on the ground
- Black polyethylene
- Clear polyethylene
- Volcanic cinders
- Wood chips
- No mulch (control)

Third-year survival of 3-0 stock was disappointing (table 2). Mulches were ineffective due to their destruction by wind and weather (Rietveld and Heidmann 1974). However, in other studies using rocks or herbicide-deadened grass as mulches, survival has consistently exceeded 90% (Heidmann 1963).

Table 2.—Survival and height of planted ponderosa pine seedlings by mulch treatment, at end of the first year and at conclusion of the study on Watershed 12.

	Survival		Height	
Mulch[1]	1968	1970	1968	1970
	Percent		*cm*	
Petroleum	65	31	7	25
Black polyethylene	61	38	7	26
Clear polyethylene	65	42	7	25
Cinders	64	40	6	23
Wood chips	69	26	6	25
Control	63	36	7	24

[1]*Each mulched spot was 18 inches square.*

Watershed 9

In 1971, four cleared strips with north, west, southwest, and south aspects were planted with ponderosa pine (fig. 4). The soil was a Brolliar

Figure 4.—An aerial view of the uniform strip cut on Watershed 9. Four cleared strips were selected for planting on this watershed.

very stony loam on 0% to 10% slopes (Williams and Anderson 1967). On each strip, four replications were established. Each replication (major plot) was split perpendicular to the strip into two equal subplots. One of the subplots was chosen randomly for slash burning while slash was removed by hand from the other subplot. During the first week of April, 7 rows of 10 trees (3-0) each were planted parallel to the edge of the timber and at 8-ft intervals, starting 8 ft from the existing stand on each plot. Plots on each aspect were fenced to exclude livestock.

Survival after two growing seasons was poor (table 3), but significantly better on the south aspect than on the other three (P = .025). Seedling survival was most uniform in the center of the strips. The major cause of mortality was lack of precipitation in June after planting followed by a very dry July (table 1). The first 5 mo of 1972 were the driest in history in northern Arizona.

Because of the poor results from the 1971 study, another regeneration study was begun in 1972. The area was prepared by spraying vegetation with dalapon and atrazine from a backpack mistblower.

In July 1973, plug seedlings and seed spots were planted on the plots. The seedlings were planted in March after being raised in styrofoam flats. There were eight replications on each strip. On each replication, two rows of 10 plug seedlings each were planted across the strips. Each plug was approximately 1 inch in diameter and 4½ inches deep. Soil moisture conditions at time of planting varied from wet to dry. Three rocks were placed around each seedling to provide some shelter and to help retain soil moisture (Heidmann 1963, Rotty 1958). Live vegetation on the plots varied, and some hand scalping was done where needed. Two rows of 10 seed spots each, with seed viability of 85%, were also planted across each plot. Five seeds were placed in each spot and covered with approximately one-half inch of soil.

Stocking in seed spots sown in 1973 was low—less than 1% of spots stocked by October (table 4)—even though precipitation in July and August was about normal (table 1). Seedlings died because of drought in September and October 1973 (table 1). There were no stocked spots by the end of the study in 1974.

Plug seedlings planted in July 1973 and mulched with rocks did well until the drought period. The 84% survival at the beginning of September was reduced to 47% by the end of the month (table 4).

The size of plug used in this study was 4½ in deep, which may be too shallow for use in Arizona. In another study, seedlings in 4½-in plugs planted in a basalt soil in October had a survival of 95% the following May. After the spring drought, however, most of these trees were dead.

Table 3.—Percent survival of planted ponderosa pine after two growing seasons, by distance from existing timber stand and slash treatment on Watershed 9.

Aspect	Slash treatment	Distance from edge of timber (feet):							
		8	16	24	32	24	16	8	Aver.
North	Burn	5.0	7.5	10.0	20.0	10.0	12.5	15.0	13.2
	Remove	0.0	22.5	20.0	12.5	10.0	12.5	27.5	
West	Burn	30.0	15.0	10.0	20.0	25.0	2.5	2.5	14.5
	Remove	10.0	30.0	20.0	15.0	10.0	5.0	7.5	
Southwest	Burn	7.5	5.0	12.5	15.0	22.5	15.0	17.5	16.8
	Remove	17.5	10.0	22.5	25.0	22.5	22.5	20.0	
South	Burn	32.5	22.5	42.5	30.0	35.0	35.0	32.5	28.7[1]
	Remove	32.5	22.5	15.0	42.5	17.5	25.0	20.0	
Aver.		16.9	16.9	17.8	22.5	19.1	16.2	17.8	

[1]*Different from other aspects at p = .025*

Table 4.—Percent stocking of original seed spots and survival of planted trees on Watershed 9 in 1973.

Aspect	Spots stocked			Tree survival		
	8/30/73	10/1/73	11/21/74	8/30/73	10/1/73	11/21/74
North	2.5	1.9	0.0	79.4	46.9	16.9
West	1.9	0.6	.0	80.0	45.0	10.0
Southwest	0.6	.6	.0	85.6	36.2	7.5
South	1.9	.0	.0	90.0	58.1	26.2
Aver.	1.7	.8	.0	83.8	46.6	15.2

Watershed 14

In 1971, a ponderosa pine regeneration study was begun on irregular cut strips at Watershed 14 (fig. 5). The logging slash on each treatment plot was disposed of by piling and burning (November 1971), chipping (August 1971), or crushing (August 1971). Chips from a portable chipper were hand spread to assure uniform distribution over the plots. Slash was crushed with a small tractor. The slash treatments were eliminated on mechanically scalped and broadcast seeded plots. Herbicides were applied in the late summer of 1972. Dalapon and atrazine, each at 5 lb of active ingredient per acre, were applied in approximately 8 gal of water with a backpack mistblower.

The study consisted of three replications of the following treatments on the prepared strips:

Planting of 2-0 stock on chemically prepared plots

Broadcast seeding and raking on mechanically prepared plots

Spot seeding on chemically prepared plots

Seedlings were hand-planted in May 1973, following late snowmelt. Spacing was varied randomly from 6 by 6 to 8 by 8 ft. Number of planted seedlings per acre varied due to these differences in planting density. Mil-acre inventory plots, 24 per slash treatment, were established later in a grid over the treatment plots, and the number of planted seedlings in each was determined. Seeds were sown July 12-13, 1973, at the beginning of the summer rainy season. Seed of local origin, having an average germination of 87%, was used. Each slash treatment plot was divided into two subplots to test two seed application rates: 4 and 8 lb of viable seed per acre. Seventy-five seeds were sown (broadcast, or 15 spots of 5 seeds) in each mil-acre inventory plot to accomplish the 4 lb-per-acre rate, and 150 seeds per mil-acre for the 8-lb rate. Seeding and planting success was measured in 1973 and 1974.

Figure 5.—An irregular cut strip planted with ponderosa pine following the piling and burning of slash.

Spot seeding was nearly a total failure, with a maximum of only 56 seedlings per acre after two growing seasons (table 5). The broadcast and rake treatment was only slightly better, with a maximum of only 111 seedlings per acre. The success ratio was very poor: the highest number of seedlings per acre (111) represented only 0.17% of the viable seed sown. Drought in the fall of 1973 undoubtedly was a major cause of high seedling mortality.

Planting was much more successful than seeding (table 5). There were no significant differences in percent seedling survival among the slash treatments, although survival on piled and burned plots was 14% greater than on crushed plots. All of the planted plots are adequately stocked based on a minimum of 600 well distributed seedlings per acre.

Conditions for planting seedlings were good in 1973. Precipitation was well above average in late winter and early spring. Competing vegetation had been largely eliminated, and the trees, which were in good condition, were planted properly.

Natural Regeneration Inventories

In addition to the reforestation studies mentioned, several inventories of natural seedling establishment were made on the treated watersheds. Watershed 9, stripcut in 1968, was inventoried in December 1969 (fig. 4). Fixed 1/200-acre plots were centered over each of 344 inventory points, and all live seedlings appearing since the watershed treatment were tallied. Each plot was classified as follows:

Road
Stream channel
Within center two-thirds of 120-ft leave strip
Within outer one-sixth of 120-ft leave strip
Within center two-thirds of 60-ft cut strip
Within outer one-sixth of 60-ft cut strip
At edge of cut and leave strip

Only 57 (17.0%) of the total plots were stocked with at least one seedling in 1969 (table 6). Of these, 40 (70%) were on areas that had been

Table 5.—Seedling survival 2 yr after planting and seeding on three slash disposal treatments at Watershed 14.

Regeneration method	Slash treatment	Seeding rate	Seedlings/A after two growing seasons	Success after 2 yr
		Lb/acre	*Number*	*Percent*
Plant 2-0 stock	P and B[1]	—	600	91.50
Plant 2-0 stock	Chip	—	736	87.70
Plant 2-0 stock	Crush	—	597	77.10
Seed spot	P and B	4	0	0.00
Seed spot	P and B	8	56	.04
Seed spot	Chip	4	28	.04
Seed spot	Chip	8	0	.00
Seed spot	Crush	4	0	.00
Seed spot	Crush	8	56	.04
Broadcast and rake	P and B	4	0	.00
Broadcast and rake	P and B	8	28	.02
Broadcast and rake	Chip	4	111	.17
Broadcast and rake	Chip	8	83	.06
Broadcast and rake	Crush	4	83	.13
Broadcast and rake	Crush	8	83	.06

[1]*Pile and Burn*

Table 6.—Natural regeneration of ponderosa pine seedlings on Watershed 9.

Plot classification	Total plots	Stocked plots: 1969 Inventory		1975 Inventory	
	Number	*Number*	*Percent*	*Number*	*Percent*
Road	7	0	0	4	57.1
Stream channel	10	2	20.0	3	30.0
Center 2/3 of leave	94	18	19.1	57	60.6
Outer 1/6 of leave	116	24	20.7	66	56.4
Center 2/3 of cut	31	1	3.2	19	61.3
Outer 1/6 of cut	35	3	8.6	20	57.1
Edge of cut & leave	51	9	17.6	20	39.2
Total	344	57	17.0	189	55.0

burned before the moderate seedfall of 1968 (Larson and Schubert 1970).

In the cut strips, where slash burning was attempted before the 1968 seedfall, seedlings most often were found under unburned or partially burned logs in slash piles. This may have been due to shading and moisture availability. Grasses and forbs have invaded most of the cut strips, creating a competitive situation for seedlings. In leave strips, seedlings often were found in areas where slash fires crept into the strip and removed the humus layers and killed the herbaceous seeds. Total stocking was quite low, with a watershed average of 111 seedlings per acre.

By July 1975, when the watershed was inventoried again, the average stocking had increased to 371 seedlings per acre. Overall, 55% of the 344 plots inventoried were stocked. Stocking was distributed equally between cut and leave strips, averaging 59% within each category (table 6). Fewer edge plots were stocked, but no trend was apparent.

Another early inventory was made in 1968 on the 455-acre cleared Watershed 12 in 1966, 2 yr after treatment (fig. 3). The inventory was made on 1/200-acre plots centered over 197 inventory points. Of these, only 16% were stocked. Seedlings on 5% of the plots were less than 2 yr old and had germinated after treatment. Seedlings on 11% of the plots were established before the trees were cleared. Seedlings established after treatment were found as near as 2 chains from the watershed boundary (and nearest seed source) and as far as 15 chains. There was no apparent invasion of seedlings along any portion of the watershed boundary, with all evidence pointing to germination of seed that fell prior to treatment.

On Watershed 12 there were approximately 38 ponderosa pine seedlings per acre 2 yr after treatment. Another inventory in June 1975, 9 yr after treatment, found 109 seedlings per acre, mostly 4 to 7 yr old. The 1975 inventory supported earlier results of no trend of seedling establishment with respect to nearness of seed source, and while some seedlings may have germinated from wind-blown seed, others may have come from dormant seed. Some of these seedlings were in the center of the watershed, 2,000 ft from the nearest seed source.

Watersheds 11, 14, and 17 were inventoried in June 1975. The treatments applied to these watersheds were: cleared and grazed, irregular strip cut, and thinned to 30 ft^2 of basal area per acre, respectively.

Watershed 11 had the lowest stocking with less than five seedlings per acre—most likely a result of initial competition from seeded grass and intensive grazing every spring and fall.

Watershed 14 had 221 natural seedlings per acre scattered throughout both cut and leave strips, with no apparent trend of preferred sites. Many of the seedlings inventoried on Watershed 14 in 1975 originated from the 1971 seed crop. Seed traps distributed over the Watershed 14 regeneration study in the fall of 1971 indicated average seedfall was approximately 4 lb per acre (table 7), which is considered a medium seed crop (Larson and Schubert 1970). Inventories revealed rather small numbers of surviving seedlings after two growing seasons. The pile and burn slash treatment (fig. 5) received the heaviest seedfall (6.6 lb per acre), and also had the largest number (90) of seedlings per acre. The seed to seedling ratios indicate large amounts of seed are required under natural conditions to produce relatively few seedlings.

Table 7.—Seed production in 1971 and seedling survival on Watershed 14 in 1973.

Slash treatment	Seedfall	Seedlings after two growing seasons	Seeds/ seedling
	Lb/acre	*No./acre*	
Pile and burn	6.6	90	880
Chip	2.0	14	1,714
Crush	3.3	28	1,414

The severely thinned Watershed 17 had 70 established seedlings per acre 6 yr after treatment. The seedlings were scattered and not related to seed source, as on Watershed 12.

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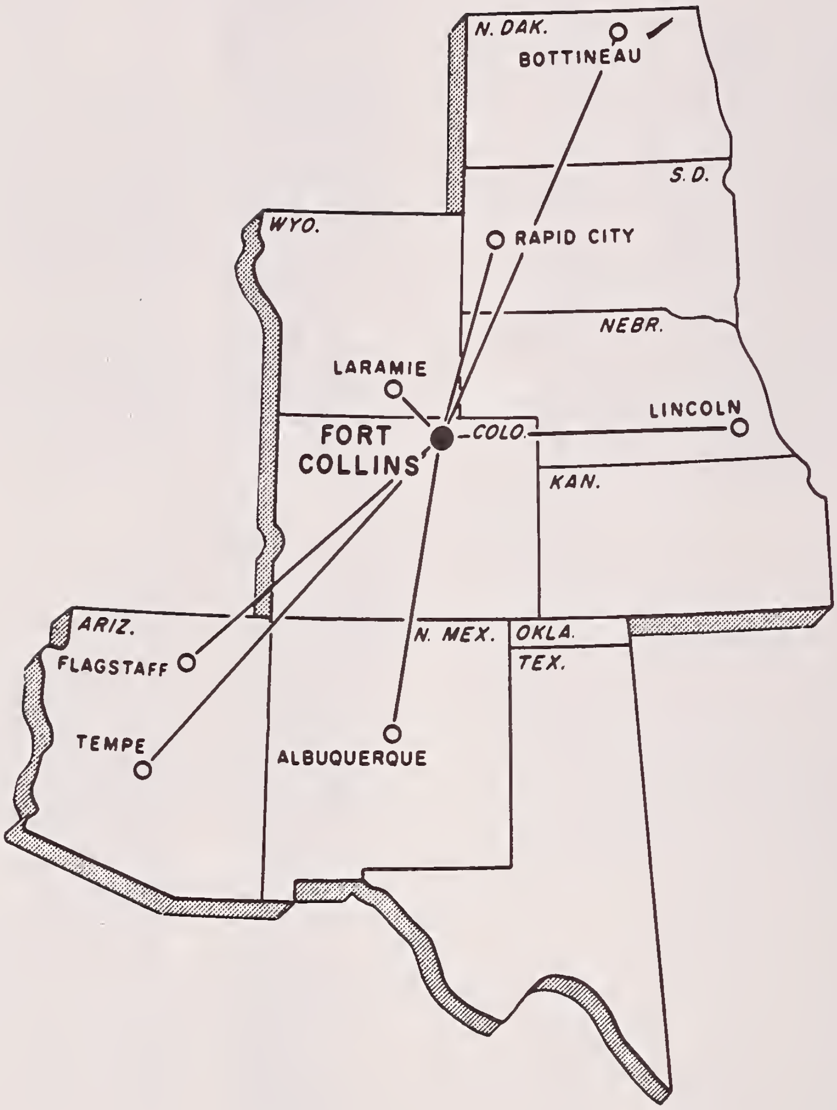
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